The American Institute *of* Consulting Engineers, Inc.

ENGINEERING PAST AND FUTURE

AN ADDRESS BY

COLONEL GEO. D. SNYDER

AT ANNUAL MEETING
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Engineering Past and Future

"The power to read the future is not given to man, but by a study of the past he can at least more or less intelligently plan for the near future. The engineer who builds structures with a life of many decades, or perhaps centuries, must consider the future if he is to plan wisely.

Originally engineering was largely obstructive and destructive, but the modern engineer is more engaged in removing, surmounting and piercing obstacles and barriers to commerce and communication than in creating them. From Hadrian to Hindenburg the attitude towards such things has changed, and to-day it would be more difficult to finance the construction of a Chinese wall than to build it.

"For five years the engineer perforce reverted to his primordial practices, but he is now engaged in making good the damage done, and will soon resume his work as a pioneer in the march of progress.

"During this temporary inactivity it is perhaps well to take stock of what the engineer has accomplished in the past and consider what the world will expect of him in the future.

"It is surprising when one considers it how much the work of the engineer has had to do with the creation of means of transportation and communication and these facilities have made the concentration of population in large numbers in cities possible and this has in turn made necessary the removal of waste products so that these dwellers would not perish in their own filth, all problems for the engineer.

"The early engineer built roads, aqueducts, sewers, canals, and with the invention of the steam engine and its application to land and water transportation, railways, bridges, tunnels, harbors, ship canals, and improved rivers for inland navigation, together with numerous works to supply man's needs, and

to make life possible in areas where men could not live without engineering structures to make the land habitable.

"The practice of engineering has been constantly changing and developing in the past and will continue to do so in the future, and in studying the past as a guide to the future it is necessary to obtain more or less authoritative data on which to base conclusions. After searching the available literature, it was considered that the scope of the papers presented at various International Engineering Congresses was representative of engineering thought at the various dates, so that the following have been used—That at Chicago in 1893, at St. Louis in 1904 and at San Francisco in 1915. To the above have been added 'Achievements in Engineering,' by L. F. Vernon-Harcourt, first published in 1891, as more representative of certain phases of engineering in foreign lands than the above Congresses, and as indicating the aspect of our own accomplishments through other eyes, the work treating more of record-breaking achievements than of the average or normal practice covered by the Engineering Congresses. It may not be significant but is worthy of remark that the Teutonic nations were largely represented in the Congress of 1893 but did not appear in 1904 and, owing to the War, could not take part in 1915.

"It should be noted that these Congresses have occurred at intervals of eleven years and that the next will be due in 1926. The City of Philadelphia is now considering the advisability of celebrating the Sesquicentennial of our National Independence at that time, which would be a fitting occasion for the next Engineering Congress.

"The above may be called mile stones on the path of our engineering progress or range points from which to project a path into the future.

"The subjects considered have been classified and are indicated in the accompanying table. This table speaks for itself and a study of it reveals some curious omissions and some overemphasis of certain phases of the art, but this is largely due to the fact that the submission of papers was voluntary

and the men competent to describe certain works or branches of engineering were too busy to do so, or the subject had been dealt with previously, or could be covered better at a later date.

"Aside from the above, the papers presented may be considered as representative of engineering practice at the time, and reference will be made to certain omissions and to bringing the engineering progress down to the present year.

"It is not proposed to describe these papers in detail but only to refer to their general scope and to make certain comments on the general trend and development.

"City Transit:

"In no field of engineering has greater progress been made in the past thirty years than in that of City Transit, and in none is there need for still greater facilities. In 1891 when Vernon-Harcourt's book was first published, London had its Metropolitan Underground Railway, Berlin had a Metropolitan Railway crossing the City east and west on a viaduct, and New York had its elevated railways, all steam operated. Paris had an underground line under consideration.

"Looking back into the light of our present knowledge of the tremendous influence of electric traction on city transportation, it seems strange that no reference was made to the City and South London Railway opened and operated electrically in 1890, or to the Buda-Pest subway then approaching completion and operated electrically in 1893.

"Since 1915 but little has been done in the countries that participated in the War. In America, New York is completing its authorized lines; Boston has completed the Dorchester Tunnel extension of its subway system and Philadelphia has made some progress. Chicago has not yet started its proposed underground system and Cincinnati and Cleveland have projects under consideration.

"In the countries not participating in the War, Madrid has a system just opened, and the Buenos Aires Western Railway has constructed an underground freight line to the port lines and a passenger line from its terminal station to a joint underground interchange station.

"The 1920 census of the United States indicates that although the war has materially checked the growth of population in this country as a whole, the movement of population to the cities has continued and the need for additional city transportation will continue.

"The problem in the immediate future is financial, rather than technical, due to the increasing cost of construction and uncertainty as to sufficient revenue to be obtained from the prevailing fares to permit profitable operation or to allow of financing any new projects.

"In the United States the earlier lines were built and equipped by private companies, the later ones were built and owned by the municipalities and equipped by the corporation obtaining the franchise for operation. In Great Britain the transit lines were built and operated by private corporations, while in Paris the structures are built and owned by the municipality and equipped by the operating company.

"Looking into the future it would seem that the manifest tendency for the life of the city to be segregated into financial, commercial, manufacturing, shipping, amusement and residential areas will continue and with the tendency for shorter hours of labor, better housing and improved and more rapid transportation, an increasing proportion of the inhabitants will reside in the suburbs in garden communities.

"This is an element in the broader aspects of city planning and will be referred to again under municipal engineering.

"Railways:

"During this period a tremendous development in railroad construction took place not only in this country but in Canada, Spain, Africa, and South America.

"The chief fact to be gleaned in studying the progress in the past thirty years is the change in the viewpoint. In 1891 the obstacles in the path of railway progress were the distant Alps, Andes and Rockies, while to-day our mountains are nearer home and we have such obstacles as inadequate harbor and city terminals, insufficient tracks, yards and shops to enable the rolling equipment to be more constantly and efficiently used.

"As the aggregate length of railways of the world increases each new line constructed becomes a relatively smaller part of the whole than in the past and the percentage of engineers engaged on the location and construction of new lines becomes small compared with the numbers engaged in the operation, maintenance and improvement of existing lines.

"In the older countries few new lines will be built but the tendency will be to improve the gradients on through routes of existing mountain railways by tunnels and developing distance, and to an increase in the use of electrical power on gradients and elsewhere where there is a heavy concentration of traffic to provide additional tracks and terminal facilities.

"Developments in the art of telegraphy, telephony, radiotelegraph and the use of the aeroplane in the transportation of mail has reduced the relative importance of the railway in the transmission of information, and it is not likely that any essentially mail routes will be constructed in the future.

"The tendency also is to relieve the railway of the burden of transporting substances that can be otherwise conveyed, such as water in aqueducts and pipes, oil in pipe lines, and power in electric cables, rather than in the form of fuel. Pipe lines have long been used from the oil fields in the coast and centres of consumption, and one is now under construction from the coast to Paris.

"Natural gas in the United States has long been conveyed for great distances in pipes from the production fields to the points of consumption and there is no reason why this cannot be done with artificial gas as well. In the event of the failure of the natural product it may prove an economy to generate the gas at the coal fields and pipe it to the centres of consumption.

"Railway development in the past has largely been along the lines of parallels of latitude, but much of the future development is likely to be North and South to make available the development of resources of the southern hemisphere.

"However dark the immediate outlook may be, the indications are that in the near future there will be a tremendous

amount of railway work, not so much in new lines as in the improvement and development of existing routes and in the providing of additional equipment and facilities, including the increasing use of electric power and in increasing capacity and safety of existing tracks by greater use of automatic signals.

"The increase in train loads is continuing but it would seem that we are approaching the maximum possible within our established clearance limits and our present methods of road-bed and track construction.

"In this connection it should be noted that in 1902 new railway construction in this country reached its maximum, with a length of 6,000 miles, which has more or less gradually been reduced to 686 miles in 1919, which is practically equal to the length of line abandoned in that year, while in 1920 only 314 miles of new line were constructed.

"While short lines of railway have been abandoned from time to time it is only from 1917 on that this has reached large proportions in the United States as follows: 1917, 1,338 miles; 1918, 1,283 miles and 1919, 648 miles. This may have been influenced by war conditions and consequent high prices but it would seem that highway development and motor transport has had much to do with it. It is not improbable that in the development of future transportation facilities of a given area that the railway and motor transport will be inter-dependent elements in a joint system, the longer through routes being by railway and the motor vehicles taking the place of a large portion of the network of branch feeders.

"The problem of diverse gauges in South America, Australia and in many countries as development progresses and the present more or less isolated systems are connected will have to be met and an engineering solution found.

"Subaqueous Tunnels:

"Excepting incidentally in connection with city transportation none of the Engineering Congresses adequately discuss subaqueous tunnels.

"Vernon-Harcourt devotes considerable space to this subject and describes the Mersey, Severn and Sarnia railway tunnels at that time completed and in operation with steam loco-

motives; the Thames subway, a foot passage; the Hudson & Detroit projects then partly constructed and abandoned, and the project for the Channel Tunnel between England and France.

"The development of electric traction has had a marked influence on this branch of engineering, since they were first worked the Mersey and Sarnia tunnels have been equipped for electric propulsion and all the newer trunk line tunnels have been so operated from the start.

"In addition to railway tunnels various subaqueous tunnels for conveying gas and water pipes have been built, including two tunnels for gas pipes under the East River at New York, the Catskill Aqueduct crossing of the Hudson River, as well as various water intake tunnels of the cities of the Great Lakes, and other similar works in various parts of the World.

"In the light of our present knowledge of the development of highways due to the automobile and motor truck, it is strange no reference is made to Highway Tunnels in our table. The first subaqueous tunnel built—Brunel's Thames Tunnel completed in 1843—was constructed as a highway tunnel although never used as such. Two subaqueous tunnels with the largest diameter ever constructed at that time, the Blackwell Tunnel, 27′ 0″ diameter and the Rotherhithe Tunnel, 30′ 0″ diameter, are highway tunnels. Three such tunnels have been constructed under the Chicago River, one under the Clyde at Glasgow and one under the Elbe at Hamburg, and construction has started on a larger project than any, the highway tunnel to cross the Hudson River between New York and New Jersey.

"Considering the continued growth of maritime cities and the interference of low level bridges with water-borne commerce, the outlook for underwater tunnels is good.

"Bridges:

"Two chapters of Vernon-Harcourt's work are devoted to bridges, one to the general principles of design and the other to a description of typical examples, those selected giving the type and maximum span and clear height from water surface, being as follows:

		Maximum Span	*Clear height above water*
Forth, ...	Cantilever, ...	1,700 ft.	150 ft.
Brooklyn, ...	Suspension, ...	1,595.5 ft.	135 ft.
St. Louis, ...	Steel Arch, ...	520 ft.	
Garabit, ...	Steel Arch, ...	541 ft.	401 ft.
Hoogly, ...	Cantilever-Truss, .	520 ft.	
Hawkesbury, ,..	Truss, ...	416 ft.	40 ft.
Tower, ...	Bascule, ...	200 ft.	139½ ft.

"These examples were the longest spans of their respective classes at that time but have since been exceeded as follows:

"The Forth, a cantilever of 1,700 feet span by the Quebec of 1,800 feet.

"The Brooklyn, a suspension of 1,595.5 feet span by the Williamsburg of 1,600 feet.

"The Garabit, a steel arch, of 541 feet span by the Hell Gate of 977.5 feet, and

"The Hawkesbury, a truss, of 416 feet span, by the Municipal Bridge at St. Louis, with a span of 677 feet.

"A study of the development in bridge engineering in the past thirty years shows some startling changes, not so much in the record spans of various types, which have been only slightly exceeded, as in the ordinary practice. In 1891 timber was still used and excepting for a few pile and trestle structures it has disappeared. Steel has been substituted for iron, concrete for cut stone in piers and arches, and solid ballasted floors for the open floors for railway bridges.

"The big change, however, has been in the increase in railway train loading and this increase has compelled the renewal of most older bridges rather than any deterioration due to time.

"In a similar way the development of the automobile and motor truck and consequent greater loads and impact due to higher speed will necessitate the reconstruction of many highway bridges.

"The most marked change in this field however in this period is that at the beginning of it each engineer made his own specifications while now this tendency is towards uniformity by the

use of standard specifications started by some pioneers such as Theodore Cooper and continued by various technical societies.

"The future of bridge engineering is good, first in the strengthening, widening and renewal of existing structures; second, as part of the tremendous development and reconstruction of highways; and third, by the bridges necessary for the roads and railways constructed in developing new territory.

"While bridge structures of great magnitude will be required from time to time as in the past they will form but a small percentage of total work to be done.

"Submarine Mining and Blasting:

"Much space in the engineering literature of the past thirty years has been devoted to this subject.

"Some recent work in the United States has been done by enclosing the area to be excavated by a coffer dam, unwatering and then drilling, blasting and removing as on the land.

"Much work of this class will be required in connection with river and harbor work in the future.

"Ports and Waterways:

"This subject was well covered at the various congresses and also by Vernon-Harcourt, as it was one of his specialties.

"Increase in ocean commerce, changes in world's routes and the check in normal development due to the war, necessitate a tremendous amount of port improvement in the near future. The problem in great ports is so broad that the general lines should be determined jointly by engineers experienced in harbors, railway, city planning and inland and coastwise navigation.

"In marine transportation as in railroading, where the engineers have been struggling to keep pace with the increasing train loads, the harbor engineer has to provide for the increasing draft of vessels. An economic draft of 60 feet is now talked of as possible in the not distant future. This would necessitate a tremendous development in dock, lock, ship canals and dry-docks. With such plans for the future it would seem

that there was much work in prospect in this branch of engineering.

"Various more or less important works are not included in this tabulation, including the Kaiser Wilhelm Canal, the New York State's barge canal, and the Cape Cod Canal.

"This work is subject to legislative authorization and appropriation and the future cannot be foretold, but there is a demand for improved waterways, not only in this country but in foreign lands. The need for better facilities for ocean going ships between the sea board and the Great Lakes is being felt.

"Reference should be made to the canal tunnel recently completed near Marseilles which has a clear internal span of 72 feet, with a length of over four miles.

"Attention should also be directed to the fact that in the United States with the exception of on the Great Lakes, notwithstanding the huge sums spent on improvement to the inland waterways, that traffic has steadily fallen off. In South America and to some extent in Africa the railways are supplementary to the rivers and are used to overcome the obstacles due to rapids, falls and the like. Whether or not the history of the United States in this respect will be repeated in these countries, that the waterways will be unable to compete with the railways when a complete system is constructed, is a problem to be considered.

"Water Supply:

"The trend of population to cities and the increasing attention given to safeguarding the public health has led to a large amount of work in the domain of water supply engineering, as indicated in this table and much more work will be necessary in the future.

"Light Houses:

"The last chapter of 'Achievements in Engineering' describes the Eddystone Light House and the Eiffel Tower. No related subjects were covered in the Congress of 1893, but the Congress of 1904 discussed the light houses of France, coast

lighting in Great Britain and in the United States. Light houses were not discussed at the Congress of 1915 excepting in connection with aids to navigation for the Panama Canal. No monumental structure has been built since 1891 exceeding the height of the Eiffel Tower (984 feet) but various utilitarian office buildings approaching it in height have been constructed as follows:

Woolworth Building, ...	55	stories	760	feet	high
Metropolitan Life, ...	48	"	658	"	"
Singer Building, ...	41	"	612	"	"
Equitable Building, ...	36	"	542	"	"
City Hall, Philadelphia, ...			537	"	"

"Building and zoning restrictions are likely to limit the construction of such structures in the future. In addition to the architectural features of such a building, the technical structural design, the elevators and other mechanical features form an engineering problem of great magnitude.

"Irrigation:

"Irrigation was not discussed by Vernon-Harcourt or by the Congress of 1893, but was discussed at subsequent Congresses.

"Much of the early irrigation in the United States was done by individuals or corporations but most of the recent big work is being done by the United States Reclamation Service. The indications are that there is a great need for the irrigation engineer in many districts both in this country and abroad.

"The converse of irrigation is prevention of floods, reclamation of submerged lands by embankments and drainage. Much of this has been along our great rivers and more is likely to be undertaken. No great projects of winning land from the sea, such as the great works in Holland, have been undertaken in this country, but as population becomes more dense and land more valuable the demand for engineers to solve such problems will occur.

"Various projects for drainage and flood protection have been proposed or undertaken, the largest of which is the Miami Conservancy now under construction.

"Municipal Engineering:

"The only branch of Municipal Engineering discussed in 'Achievements of Engineering' was water supply, but the various Engineering Congresses have discussed the different phases of this subject with more or less thoroughness.

"It is strange that none of these Congresses refer to the Chicago Drainage Canal, which was one of the biggest municipal works ever undertaken.

"The outlook for the future is good on account of the continued drift of population to the cities, the postponement of work during the War Period and the great amount of municipal work incidental to the relief of the housing situation.

"Materials of Construction:

"One of the marked developments during the period covered by this review of engineering progress is the increased knowledge available to the engineer as to the properties of materials of construction, some developed by various departments of the United States Government and some by the American Society for Testing Materials.

"Mechanical, Electrical, Mining, Metallurgical:

"Although a few papers were presented in 1893 and 1904, the Congress of 1915 was the first to adequately discuss Mechanical, Electrical, Mining and Metallurgical Engineering. Inventions in these branches of the profession not only create a large amount of the work for the engineer but provide the means and materials for its execution so that the interrelation of the various branches of engineering becomes manifest.

"Chemical engineering was only covered incidentally in connection with other branches and attention should be directed to this field of endeavor for the engineer, the chemist and physicist and co-operation in the solution of many difficult problems of great benefit to mankind.

"Military, Naval and Marine Engineering:

"Military engineering was covered in 1893 and 1904 but was not discussed in 1915. The developments and changes due to the war have practically wiped out the old art of mili-

tary engineering as practically all branches of engineering were found to have a military function. What is needed in the future is for the Army technician to have a broad knowledge of the art of war and its problems, and an intimate knowledge of the development and resources of the engineering world so that he can commandeer the personnel and material needed to solve his war problems.

"The civilian engineer also needs a broad knowledge of military art, and a close knowledge of the application of his branch of the art to its military uses, and should cultivate intimate relations with the Army engineer so that they can think and talk in a common language and work together for a common end.

"The war demonstrated that the engineer by his training and adaptability was a useful element in the war machine. The assembling, supply and direction of the men and machinery and supply of material at some more or less inaccessible point for the execution of some great engineering project is more like some war problem than the work of any other profession, as is the disbanding and dispersal on the completion of the work similar to transition from a war to a peace status.

"As a gainful occupation it cannot be said to have a bright future but as a means of making the world safe for the engineer to develop its resources for man's use and convenience it is necessary and should not be allowed to fall into desuetude.

"The Congress of 1915 devoted much time to Marine Engineering and covered not only war and merchant vessels, but dry docks and cargo handling as well.

"As stated under harbor engineering this should have a bright future both at home and abroad.

"Conclusions:

"Having thus made a survey of engineering for the past thirty years, one cannot fail to observe certain remarkable changes and developments:

"1st—The achievements in engineering at present are not so much monumental structures of unprecedented magnitude, as were those of thirty years ago, as in a vast improvement in

the average efficiency and uniformity of practice and in the improved resources at the engineer's command.

"2nd—That the development of the resources of the world by improved means of transportation is still the main task of the engineer, not so much in providing new routes as in improving and developing the old ones.

"3rd—That the continued concentration of people in cities is likely to give municipal engineering in all its branches a very active future; city planning, supplying water, fuel and light, removing sewage, refuse and garbage and furnishing internal transit, furnish problems requiring the best technical skill in their solution.

"4th—The development of motor transit is leading to a great improvement in highways and will require the services of engineers for many years to come not only in the construction of roads but in highway bridges and tunnels as well. Congestion of this traffic may require the separation of heavy motor truck, light passenger cars and pedestrians at crowded points in the interest of safety and increased capacity.

"5th—The oil industry is likely to require the services of engineers in the production, transportation, refining and distribution. New fields will be discovered and if the natural supplies fail to equal the demand, the compactness and convenience of power in this form is so great that an artificial supply in a gaseous or liquid form will doubtless be furnished.

"6th—The increasing price and scarcity of fuel is leading to a renewed study of the development and transmission of hydro-electric power.

"7th—The greater magnitude of manufacturing plants is creating a demand for technical men who specialize in their arrangement, design and construction instead of adding this to the duties of one of the permanent staff of the concern already burdened with operation or administration, and this field is likely to develop further in the future.

"A study of the development of engineering leads one to the conclusion that engineers have lacked vision. Even the creators of epoch-making inventions seemed to have had little conception of the far-reaching importance of their creations.

None perceived the influence of the invention of the steam engine. Not only has it reduced man's hours of labor but it has released labor from supplying man's imperative daily need for use in creating the engineering structures that have made modern civilization. Not only in its application to manufacturing has it added to man's comfort but by its application to land and water transportation, it has created the art of engineering.

"In electricity also none foresaw its use in lighting, in transportation, in the transmission of power from natural sources, and none foresaw what the internal combustion engine was to lead to in transportation, in the air, and on the highways.

"One favorable development is the increasing influence of engineers in public affairs. It was realized during the war that in most activities the advice and assistance of the technical man was needed, and his advice and assistance is being called for in peace time activities as well.

"As to the prospects for work for the engineer in the near future, the indications are that it will be taken up approximately in the following order:

"1st—The absolutely necessary repairs, renewals, equipment and facilities postponed by the war and now necessary to handle the daily business of railways, public utilities and the like, including housing for the shifting population.

"2nd—The National, State and Municipal activities that do not need to show immediate financial return.

"3rd—Commercial and industrial activities that get a quicker return on their investment, and that can afford to pay the high cost of capital and construction.

"4th—Ordinary corporation activities that must be financed on the basis of earning the interest on the investment at an early date.

"5th—Structures of magnitude requiring a long time to construct and placed on a self-supporting basis. Activity in these lines will come last when the cost of labor, material and money has reached a more moderate and normal condition.

"Geographically the resumption of normal engineering activity will come first in those countries that have not been

hurt by the war but have profited by it, then in countries little damaged by it, such as the United States, then in the British Empire, followed by the allied, and lastly by the Central Powers and Russia, dependent on stable governments and stable financial conditions.

"Considering what the engineer has accomplished in the past three decades, and in view of the progress that must be made to meet the world's needs under new conditions, it would seem that there is much for the engineer to do in the future, and his present task is not to let the present engineering stagnation cloud his vision and hope in a future that is bound to be bright and fruitful of many technical achievements."

(For table showing Scope of Achievements in Engineering, and International Engineering Congresses, see Appendix.)

TABLE SHOWING SCOPE OF "ACHIEVEMENTS IN ENGINEERING" AND INTERNATIONAL ENGINEERING CONGRESSES OF 1893, 1904 AND 1915

Vernon-Harcourt 1891	1893	1904	1915
I—CITY TRANSIT			
London, Metropolitan		Underground Railways	London Traffic
Paris, Met. (proposed)		In Great Britain	
Berlin		In Met. of Paris	City Transit in America
N. Y. Elevated	Power Cable Railway	In United States	
	Cable Rys. (Street)		
II—RAILWAYS			
Semmering Railway	Guadalajara to Pacific	American Locomotives	Rys. Cons. and Equipt.
Brenner Railway	Railroad in Mexico	Rolling Stock France	Rys. Australia Equipt.
Mt. Cenis Railway	Railway Stations Dresden	Balanced Compound	Rys. Location
St. Gothard	Railway Terminal Cologne	British Ry. Terminals	Rys. Economic Cons.
Arlberg Railway	Railway Terminal Altoona	French Ry. Terminals	Rys. Dutch E. Indies
Rocky Mt.	Railway Signalling	Traffic Development	Rys. Russia
Western U. S.	Railway N. S. Wales	Electric Power	Rys. Status of N. & S. Amer.
Canadian Pacific	Railway Portugal	Ry. Terminals Genl.	Rys. Status Italian
Mexican Ry.	American Locomotives	Ry. Terminals French	Rys. Status India
Peruvian Rys.	Railway Location	Ry. Transportation	Rys. Status Chinese
Railway Progress	Railway Gauges	Terminals British	Rys. Terminals
			Rys. Signals and Interlg.
			Track and Roadbed
			Locomotive Development
			Rolling Stock
			Floating Equipment
			Electric Motive Power (2 papers)

1891		1893		1904	1915
III—NARROW GAUGE MOUNTAIN RAILWAYS					
Abt System					
Fell Railway					
Rigi Railway					
Pilatus Railway					
IV—RAILWAY TUNNELS					
Mt. Cenis				Ventilation of Tunnels	Tunnels
St. Gothard					Tunnels, Italy
Arlberg					Tunnels, Switzerland
V—SUBAQUEOUS TUNNELS					
Hudson (Unfinished)					
Mersey					
Severn					
Thames Subway					
Sarnia					
Channel (Project)					
Detroit (Abandoned)					
VI and VII—BRIDGE CONSTRUCTION					
Hawkesbury	416′	Memphis Cantilever	790′	Live loads for RR Brgs.	American Ry. Bridges
St. Louis	520′				
Garabit H—	401′	Superstructure and foundations		Concrete Steel Bridges	Arch Bridges
S—	541′				
Hoogly	520′			Deep Foundations	
Brooklyn	1595.5′	Engine Loading			
Forth	1700′				
Tower	200′				
VIII—SUBMARINE, MINING AND BLASTING, ETC.					
Diving Bell		Subaqueous Rock Excav.			
Rock Breaking Rams					
Hell Gate		Subaqueous Foundations			

1891	1893	1904	1915
IX—PORTS			
London		Great Britain Harbors	
Liverpool		Harbors in Holland	
Antwerp		Ports of France	
Marseilles	Plant, French Ports	Dock Works in New York	
New York	Quay Cranes, Hamburg	Sea Coast, U. S.	
	Quay Wall, Altoona	Foundations for Quay Walls	
	Glasgow Harbor	Dry Docks	Improvement Navigable Estuaries
	S. Atlantic Harbors	Dry Docks at France	
	Leixoes Harbor	Dry Docks, Temporary	Dry Docks
		Lake Harbors (Superior, Erie, Ontario)	
		Island Harbors	
		Dredging Ocean Bars	
X—HARBORS (Breakwater)			
Table Bay		Delaware	
Alexandria		Sandy Bay	
Boulogne		San Pedro	
Colombo		Concrete Blocks for	
Dover		Concrete Blocks, Osaka	
New Haven			
XI—RIVER IMPROVEMENTS			
Tyne		Artificial WW. in Gt. Brit.	Flood Control
Seine	France	Inland Nav. France	Rhine
Maas	Inland Trans., U. S.	Artificial in U. S.	Waal (Maas)
Danube	River Imp., Portugal	Natural Netherlands	Natural Waterways Russia
Mississippi	Clyde	Traffic Development	
	Wesser	Dredges, Construction Performance	Natural Waterways in U. S.
	Limits in Improvement of Rivers		River Imp., Japan
		Dredges, Gen'l Practice	Flood Control in U. S.
		Dredges, Crane and Ladder	Flood Control in China
		Dredges, Hydraulic	

1891	1893	1904	1915
XII—WEIRS AND DAMS			
Poses Weir Seine Spree Weir Lift La Louvier		Rolling Dams	
XIII—SHIP CANALS—Inland			
Amsterdam Manchester	North Sea Canal (2 prs.)	Holland Ship Canals	Waterways Ship Canals
XIV—SHIP CANALS—Inter-Ocean			
Suez Panama Nicaragua Corinth Ship Railways			Panama Canal Commercial Aspects Geology Sanitation Municipal Engineering Water Supply Working Force Purchasing Climatology, etc. Dry Excavation Locks, Dams, etc. Dredging Spillways Hydraulics Electrical and Mechanical Reconstruction Panama R. R. Terminals, Dry Docks, Wharves Aids to Navigation

1891	1893	1904	1915
XV—WATER SUPPLY			
Manchester	Underground Water Supply	Purification, Am. Prac.	
	Filtration (2 papers)	Purification, European Prac.	Water Supply, U. S.
	Distribution, Mexico	Purification, French Prac.	Water Supply, France
Liverpool		Purification for steam	Water Supply, Japan
		Ground water supply	
		Pumping Machinery (2 papers)	
XVI—LIGHT HOUSES—Monumental Structures			
Eddystone Lighthouse		Lighthouses, France	
Eiffel Tower 984'		Coast Lighting, Gt. Brit.	
Cheops 484'		Coast Lighting, U. S.	
Cologne Cath. 528'			
Washington Mon. 541'			
XVII—IRRIGATION			
		Irrigation under British Engineers	Irrigation U. S.
		Irrigation in Java	Irrigation, Economy of
		Irrigation in U. S.	Irrigation Pumping
		Irrigation, Hydraulic Motors in	Drainage
		Irrigation, Hawaiian	Irrigation, Italian
			Irrigation, Lybia
			Irrigation, Australia
			Irrigation, India
			Irrigation, Spain
			Irrigation Dams
			Irrigation, Argentine
			Duty of Water

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XVIII—SEWERAGE			
	Purification Sewage by Filtration	Sewage Disposal, Amer.	Sewerage and Drainage
	Sewage System of Milwaukee	Sewage Disposal, France	Sewage Disposal
		Municipal Refuse (2 papers)	Sewage Treatment
XIX—HIGHWAYS			
	Paving Brick	Highway Const., U. S.	Streets
		Highway Const., France	Thermal Effects and Wear
		Highway Const., Mass.	Dust
			Rural Highways
			Concrete Roads in Italy
			City Planning
	Laying Out Cities, Aesthetic Principles of		Fire Protection
			Public Utilities
XX—MATERIALS OF ENGINEERING			
	Testing Portland Cement	Test of Materials	Outlook for Iron
	Manufacture and Testing of Portland Cement	Test of Cement (2 papers)	Life of Iron and Steel Structures
		Con. & Con. Steel, U. S. A.	Alloy Steel in Bridge Wk.
		Con. & Con. Steel, France	Corrosion of Iron and Steel
		Con. & Con. Steel, Holland	Testing of Materials
		Con. Steel Bridges	Testing Full Size Members
		Manufacture of Cement	Materials of Construction
		Steel Production	Timber, Russia
		Metallography of Steel	Timber Preservation
		Test of Steel (2 papers)	Timber, U. S.
		Test of Timber	Timber, Canada
			Timber, India
			Concrete Waterproofing
			Concrete Aggregate
			Clay Products
			Concrete, Life of
			Volume Changes

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XXI—MECHANICAL ENGINEERING			
	Hoisting Machinery by Steam, Elec. or Water Pressure	Steam Turbines	Mechanical Founding
			Forging (2 papers)
			Machine Shops (2 papers)
			Automatics
			Turbines, Netherlands
			Turbines, Steam
			Diesel Engines
			Compressed Air
			Motor Vehicles
			High Temperature Flames
		Passenger Elevators	Intern'l Combustion Engine
			Boilers
			Boiler Shop Methods
			Motor Vehicles, Utility
			Motor Vehicle, Pass.
			Motor Tractors
			Safety Eng.
XXII—ELECTRICAL ENGINEERING			
	Use of Carbon in Electrical Engineering	Electrical Power	Electrical Engineering, Electric Power Station Design.
	Guadalajara Electric Light Installation	Electrical Power Generation and Transmission	Electric Motor in Industry
		Substitution, Electric for Steam	Electric Motor Influence on Machine Tools
			Electric Welding
			Electric Healing Metals
			Electric Locomotive
			Electrolysis
			High Permeability in Iron
			Electric Illuminants

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XXII—ELECTRICAL ENGINEERING (continued)			Electric Power in Canadian Industry. Water Power in Sweden. Hydraulic Power Development, Canada Hydraulic Power Development and Use Modern Water Turbine Practice Wheels of Pressure Wheels of Impulse
XXIII—MINING		Mines in France Mining Eng. in U. S.	Mining, Coal, Metals Economic and Social Influence, U. S. Valuation, Metal Mines Valuation, Oil Lands Valuation, Coal Mines Valuation, Coal Lands Valuation, Anthracite Mines Valuation, Coal Properties, W. Canada Coal Measure of France Mine Safety and Workmen's Compensation Exploration and Development Financing in U. S. Financing in Europe Organization of Mining Companies Government Relation to Mine Inspection

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XXIV—METALLURGICAL			
	Treatment of Metals for Structural Purposes		Metallurgy
	Testing Structural Steel		Symposium on Iron and Steel
	Mild Steel Structural Purposes.		Iron and Steel Casting
	Mild Steel Structural Germany		Duplex Process of Steel Manf.
			Steel Making in Electric Furnace
			Piping in Steel Ingots
			Alloy Steels
			Case Hardening of Steel
			Hardening of Steel
			Metallography of Steel
			Metallurgy of Copper
			Metallurgy of Copper Progress
			Copper Smelting
			Copper Metallurgy in S. W.
			Reduction Works, Douglas, Ariz.
			Globe District, Ariz.
			Modern Copper Plants
			Leaching Copper Ores
			Electrolytic Copper Refining (2 papers)
			Physical Properties of Bronzed Cast Copper
			Metallography of Copper
			Metallography of Copper in Japan
			Cyanide Process
			Coarse Crushing Plant
			Crushing and Grinding
			Solution of Gold and Silver
			Filtration Metal Bearing Solution from Residue

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XXIV—METALLURGICAL (continued)			Precipitation Smelting and Refining Lead Metallurgy of Zinc (2 papers) Zinc Smelting in U. S. Ore Dressing Electrometallurgy Metallurgraphy Fuels in Metallurgy Pulverized Coal in Reverberating Furnaces Utilization Fuels in Metallurgy Pulverized Coal in Copper Reverberatories Gas Producer Development Surface Combustion
XXV—NAVAL, MARINE, MILITARY		Naval Architecture in Gt. Britain Marine Engineering Marine Engineering in France Japanese Shipbuilding Torpedo Boats Japanese Vibration Fortifications Gun Construction, U. S. Seacoast Gun Carriage Ammunition Mobile Artillery Small Arms	Naval and Marine Resistance and Propulsion of Ships Ocean Freighters Japanese Shipbuilding Bulk Freight Vessels of Great Lakes River, Lake and Sound Steamers of U. S. Special Types for Coast Trade, U. S. Sail, Steam and Motor Yacht in U. S. U. S. Light Vessels

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XXV—NAVAL, MARINE, MILITARY (continued)			Battleships Submarine (2 papers) Torpedo Boats Armament Naval Warfare Marine Boilers Steam Turbines (2 papers) Marine Engineering in Japan Oil Fuel Application Diesel Engines to Marine Purposes (2 papers) Cargo Handling (3 papers) Amer. Marine Terminals Amer. Graving Dock Prac. Dry Dock, Italy
XXVI—MISCELLANEOUS	American Grain Elevators Steel Tapes for Base Lines Topographical Surveying Terrestrial Magnetism, N. A. Fundamental Units of Measure Surveying Instruments	Engineering Education Surveying Coast and Geodetic Surveying Geological	The Aeroplane (2 papers) Resistance of Air Aerodynamics Refrigeration in U. S. Refrigeration in Sweden Refrigeration in France Farm Power Equipment Agriculture and the Engineer Technical Education (2 papers) Heating and Ventilating (3 papers) Scientific Management Industrial Management Motion and Time Study Status of Engineering in Chile

NOTE—Titles abbreviated